

CONTEXTUAL EFFECTS ON THE DURATION OF EJECTIVE FRICATIVES IN UPPER NECAXA TOTONAC

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ABSTRACT

The present paper investigates the effects of word position, stress and vowel phonation on the duration of ejective fricatives in Upper Necaxa Totonac (UNT), a Totonacan language of northern Puebla, Mexico. Duration measurements were taken of frication and periods of silence occurring between frication and following vowels. Fricatives occurring in word initial position were found to be overall longer than those occurring intervocalically. Fricatives occurring at the onset of stressed syllables were generally longer than unstressed. Lateral ejective fricatives had longer frication durations in intervocalic position preceding a creaky vowel than when preceding a modal vowel. Closures that occurred between frication and vowel onset were found to be longer when the fricative occurred word initially and in stressed syllables.

1. INTRODUCTION

Upper Necaxa Totonac (UNT) is a Totonacan language spoken by approximately 3400 people living in the villages of Patla and Chicontla along the banks of the Necaxa River in the Mexican state of Puebla. The consonant inventory of UNT includes ejective fricatives in three places of articulation (alveolar, post-alveolar, and lateral), but does not include ejective stops. The vowel inventory of UNT consists of five vowel qualities /a, e, i, o, u/, in addition to contrastive length (short and long) and phonation (creaky and modal), which occur in conjunction with all vowel qualities.

Maddieson, et al [4] provide a description of ejective fricatives in Tlingit, a Na-Dene language spoken in southern Alaska and western Canada. The duration from onset of frication to onset of the following vowel was found to be quite similar at a mean duration of 223 ms for pulmonic fricatives, and 194 ms for ejective fricatives. Despite their long total durations, the ejective fricatives had shorter mean durations of frication at 148 ms than unaspirated pulmonic fricatives at 222 ms, as well as a tendency for the frication period of an ejective segment to be followed by a period of (near) silence. In word-final position, the silence associated with ejective fricatives appeared before the onset of

frication, which was taken to indicate that glottal closure occurs before the onset of frication, with a glottal release apparent after the cessation of frication noise.

The ejective fricatives of UNT have been described in a historical reconstruction and phonetic study of speech data elicited from two adult male speakers [1]. In this study, measurements were made of a small dataset consisting of several repetitions of a single word containing each of the three ejective fricatives as well as some tokens of clusters consisting of a postalveolar fricative and glottal stop. Beck reports visible glottal raising during the production of the ejective fricatives, and presents acoustic, airflow, and intra-oral pressure data. Statistical analysis was performed only on the postalveolar tokens. The mean duration of frication of the ejective fricatives was reported at 143 ms. Compared to pulmonic fricatives in clusters and immediately preceding vowels, ejective segments were found to have a shorter time to peak intra-oral air pressure, a later time to peak airflow, and a longer overall duration. The duration of silence between the end of frication and the onset of the following vowel was longer for ejective fricatives than for pulmonic fricatives in clusters.

The present paper elaborates on the findings in [1] with a larger dataset across all three places of articulation, focusing on the duration of frication and flanking periods of silence.

2. METHODS

2.1 Speakers

The speech of four speakers was analyzed for this study: 1 male in his early 60s, and 3 females, each around 30 years of age. Data was collected in the field in September 2012. Speakers were selected based on their proficiency in UNT, as indicated by self-designation and verified by other speakers within the community. Data from additional speakers were excluded due to poor recording conditions. All speakers were native to Patla or Chicontla and to varying degrees bilingual in Spanish. Interactions with the author were in Spanish.

2.2 Procedures and materials

Recordings were made in speakers' homes using a Marantz portable digital audio recorder (PMD 660) and a head-mounted Countryman earset microphone. All recordings were made at a sample rate of 44 kHz with the exception of one recording that was made at 96 kHz and subsequently resampled at 44 kHz for consistency with the remaining recordings. Speakers were prompted in Spanish to produce each item, and asked to repeat them each three times within the frame sentence /ʃla wanli ... tʃuwa/ 'he said ... now'.

The wordlist for this study was derived from the *Nuevo diccionario del idioma totonaco del Río Necaxa (New dictionary of the Upper Necaxa Totonac language)* [2], a practical bilingual dictionary compiled for the use of speakers of UNT. The list of 66 words was designed to illustrate potential variability of the three ejective fricative segments: /sʰ/, /ʃʰ/, /tʰ/. The fricatives appear in word initial and intervocalic contexts, preceding stressed and unstressed vowels, and preceding creaky and modal vowels. The phonology of UNT does not allow ejective segments in word or syllable final position, so this environment was excluded. Vowel quality and quantity were not included in the design of the wordlist, due to a lack of lexical items that would allow for a fully crossed design. Additionally, the word initial × stressed condition for /ʃʰ/ is not represented due to the lack of suitable lexical items. Two items containing /sʰ/ and one containing /ʃʰ/ were instances of the fricatives following nasal stops rather than between two vowels. Because comparable conditions were not available for all segments, these items have been excluded from the analysis.

All speakers were presented with the same list of words in the same order and asked to repeat each word in the frame sentence three times. Items that were not produced by all speakers have been excluded, resulting in 60 lexical items in the final wordlist. All repetitions of words that were produced by all speakers have been included in the analysis, resulting in a total of 686 fricative tokens (/sʰ/ n=241, /ʃʰ/ n=248, /tʰ/ n=197).

Audio data were segmented and measured using Praat [3]. For each token, annotations were made of the boundaries of frication noise and flanking silences, as well as those of any intervening bursts. Figures 1-3 below show the spectrogram of one token of each ejective fricative. Figures 1 and 2 show clear broad-spectrum energy at the end of frication indicating a burst release prior to a period of silence before the vowel onset. Figure 1 shows striations during the burst, which could indicate

glottal activity at the end of frication. Figure 3 shows a period of aperiodicity in the vowel prior to frication and lacks the clear burst at the end of the fricative, but still displays a period of silence before the onset of the following vowel. These patterns are quite typical, though there was some variation in the timing and duration of acoustic events, with the burst sometimes following the period of silence.

Figure 1. Sample spectrogram of the first two syllables of *tas'awi* /ta.sʰa.wi/ 'lose, be defeated'.

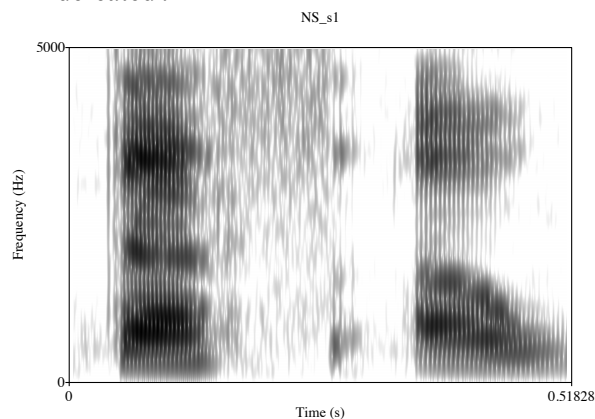


Figure 2. Sample spectrogram of *tax'a:n* /ta.ʃʰa:n/ 'shucked (corn)'.

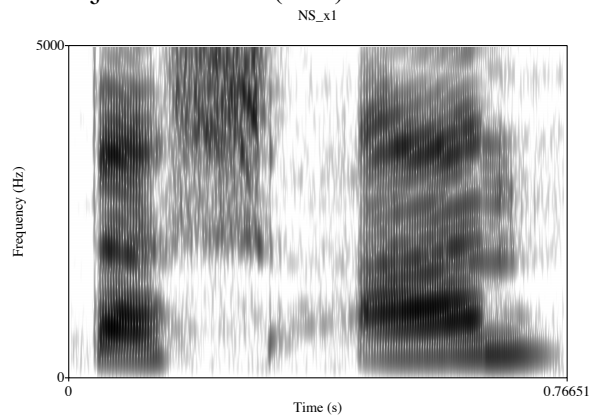
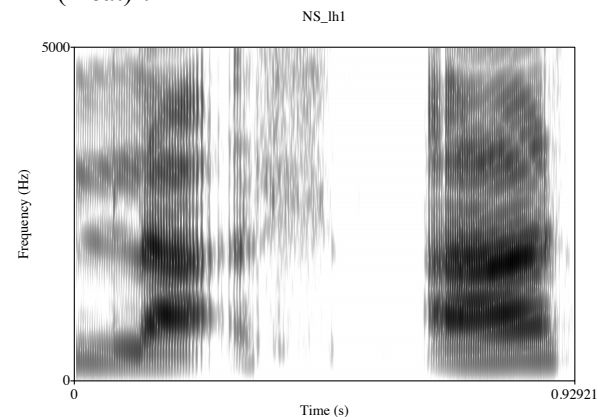


Figure 3. Sample spectrogram of *la'hlh'a:* /laʔʰa:/ 'cut something into fine strips' (meat)'.



3. RESULTS

3.1 Frication duration

Duration measures for each combination of factors were averaged over productions and lexical items for each speaker resulting in one measurement per speaker in each condition ($N = 4$). Due to lexical limitations, the three factors could not be fully crossed. Specifically, very few lexical items were found to satisfy the word initial \times stressed \times creaky condition. The analysis therefore proceeds on subsets of the data, with separate analyses for stress and phonation crossed with word position. A summary of the duration data across all conditions is presented in Table 2. A preliminary analysis was conducted comparing average durations across the three places of articulation using Welch's two-sample t -tests. Significant duration differences were found between /t'/ and /s'/ ($t(45.8) = -2.14, p < .05$), and between /t'/ and /j'/ ($t(44.1) = -2.31, p < .05$), but not between /s'/ and /j'/ ($t(49.5) = 0.21, p = 0.83$).

Table 2. Mean frication duration, rounded to the nearest millisecond, for each combination of factors.

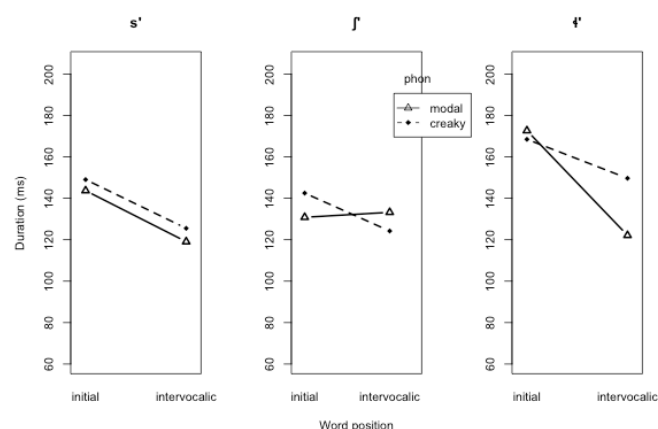
	All*	s'	j'	t'
Word initial	154	147	137	171
Intervocalic	127	122	129	131
Creaky	140	137	130	159
Modal	137	127	132	147
Stressed	141	140	130	153
Unstressed	137	127	132	151
Word initial \times creaky	152	149	143	168
Word initial \times modal	155	144	131	173
Intervocalic \times creaky	130	126	124	150
Intervocalic \times modal	125	119	133	122
Word initial \times stressed	166	159	--	173
Word initial \times unstressed	149	141	137	171
Intervocalic \times stressed	131	131	130	132
Intervocalic \times unstressed	124	113	127	131
Grand mean	138	133	131	151

3.1.1 Word position \times phonation

A three-factor repeated measures ANOVA of frication duration was performed using the factors segment (/s', j', t'/), word position (initial, intervocalic) and phonation of the following vowel (creaky, modal). The ANOVA showed significant main effects of segment: $F(2,6) = 24.48, p < .01$, and

word position: $F(1,55) = 43.55, p < .001$. The ANOVA also revealed a significant two-way interaction between segment and word position: $F(2,55) = 5.59, p < .001$, and a significant three-way interaction between all factors: $F(2,55) = 3.57, p < .05$, illustrated in Figure 4.

Figure 4. Plot of three-way interaction of segment, word position and following vowel phonation.



Pursuant to this finding, the two-factor design of word position by phonation was tested for each segment separately. The segments /s'/ and /t'/ were found to be significantly longer in initial position than intervocalic: $F(1,21) = 15.69, p < .001$, and $F(1,17) = 43.044, p < .001$, respectively. There was no significant main effect of word position on /j'/. The main effect of phonation was not significant for any segment, though it did approach significance for /t'/: $F(1,17) = 3.27, p = .089$. There was also a two-way interaction effect for /t'/: $F(1,17) = 6.03, p < .05$, but no significant interaction of phonation and word position for /s'/ and /j'.

3.1.2 Word position \times stress

A three-factor repeated measures ANOVA of frication duration was performed using the factors segment (/s', t'/), word position (initial, intervocalic) and stress of the following syllable (stressed, unstressed). The factor level /j'/ was excluded from this analysis due to missing values in the word-initial \times stressed condition. Significant main effects were found for segment with /t'/ longer than /s'/ ($F(1,3) = 69.84, p < .01$). A main effect of stress was also significant, with stressed productions longer than unstressed ($F(1,38) = 6.04, p < .05$), as was the main effect of word position, with word initial items longer than intervocalic ($F(1,38) = 51.44, p < .001$). No significant interactions were found. A two-way t -test did not find significant differences in duration

between stressed and unstressed items within each fricative category.

3.2 Closure duration

In roughly 48% of the total number of productions, a period of closure or silence immediately followed the end of frication. In approximately 33% of productions, this closure occurred after an intervening event (such as a glottal burst), for a total of about 80% of tokens with a period of silence between the end of frication and onset of the following vowel. The remaining tokens were produced with varying combinations of other phonetic events, including glottal burst and vowel onset, that are the subject of on-going analyses and will not be discussed here.

Duration measures were again averaged across lexical items and productions by speaker for the following analyses.

3.2.1 Word position *x* phonation

A three-factor repeated measures ANOVA of closure duration was performed across all closure data using the factors segment (/s', j', ɬ'/), word position (initial, intervocalic) and phonation of the following vowel (creaky, modal). The test showed a main effect of word position $F(1,55) = 11.58$, $p < .01$, with a mean duration of 98 ms for word initial tokens, and 79 ms for intervocalic tokens. There were no significant interaction effects.

The same three-factor repeated measures ANOVA was performed on only those closures occurring immediately following frication, and again on closures occurring after an intervening event. For closures immediately following frication, word position was found to be significant $F(1,44) = 9.62$, $p < .01$, (word initial: 102 ms, intervocalic: 81 ms). No significant interactions were found. No significant effects were found for closures occurring not adjacent to frication (e.g. after an intervening glottal burst).

3.2.2 Word position *x* stress

As for the frication analysis, /j'/ have been excluded from the stress analysis due to missing data. A three-factor repeated measures ANOVA of closure duration was performed across all closure data using the factors segment (/s', ɬ'/), word position (initial, intervocalic) and stress of the following syllable (stressed, unstressed). The main effect of stress was found to be significant $F(1,38) = 7.93$, $p < .01$, (stressed: 94 ms, unstressed: 84 ms). No interactions were found to be significant.

The same analyses were performed for each subset of closures as in 3.2.1. Significant effects of location: $F(1,30) = 10.41$, $p < .01$, and stress: $F(1,30) = 7.06$, $p < .05$ were found for closures immediately following frication (stressed: 101 ms, unstressed: 86 ms), but not for closures occurring after an intervening event. No interactions were significant.

4. DISCUSSION AND CONCLUSIONS

The present study provides evidence that contextual effects such as word position, stress, and vowel phonation can affect the duration of frication and silence in ejective fricatives in UNT. The segments /s'/ and /j'/ were found to be shorter than /ɬ'/. Fricatives occurring in word initial position were found to be overall longer than those occurring intervocalically, though this was not the case for /j'/ tokens. Vowel phonation was only significant for tokens of /ɬ'/, with longer frication duration in intervocalic position preceding a creaky vowel than when preceding a modal vowel.

The average duration of frication across all three places of articulation has been found to be 138 ms, which is in line with findings from previous research on ejective fricatives that found average frication durations of 148 ms [4] and 143 ms [1], and consistent with frication originating from the glottalic airstream mechanism.

Closure durations immediately following frication were found to be longer in word-initial position and in stressed syllables. These effects were lost for closures occurring after an intervening event.

Overall, findings were in line with previous research. However, in order to thoroughly understand the sound system of UNT, the pulmonic fricatives of UNT must undergo similar analyses to serve as a language-internal baseline for comparison.

6. REFERENCES

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